DOCUMENT RESUME

ED 303 504 TM 012 749

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TITLE The Use of A Priori Techniques with a MANOVA.
PUB DATE Nov 88
NOTE 22p.; Paper presented at the Annual Meeting of the Mid-South Educational Research Association (17th, Louisville, KY, November 9-11, 1988).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Error of Measurement; *Multivariate Analysis; Research Methodology
IDENTIFIERS *A Priori Tests; Contrast Coding; *Planned Comparisons; Post Hoc Tests; Type II Errors

ABSTRACT

Planned comparisons have been known for several years. Due to the availability of computers, these comparisons have become a more viable alternative to post hoc testing. There are several different types of planned comparisons that can be performed. Research goals must be well thought out when using planned comparisons, since the appropriate hypotheses to be tested need to be decided prior to analysis of data, which will also determine the type of planned comparison performed. But this foresight also allows the researcher to have increased power against a Type II error. The literature regarding the use of planned comparisons is reviewed. The superiority of planned versus post hoc tests are discussed. Six types of planned comparison coding are discussed for multivariate analysis of variance (MANOVA). (Five data tables, tabulated comparisons of contrast coding hypotheses, and an application of if/then statements for difference contrast coding are appended.) (Author)

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The Use of A Priori Techniques with a MANOVA

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ABSTRACT

Planned comparisons have been known for several years. Due to the availability of computers, these comparisons have become a more viable alternative to post hoc testing. There are several different types of planned comparisons that can be performed. Research goals must be well thought out when using planned comparisons, since the appropriate hypotheses to be tested need to be decided prior to analysis of data, which will also determine the type of planned comparison performed. But this foresight also allows the researcher to have increased Power against a Type II error.

The literature regarding the use of planned comparisons is reviewed. The superiority of planned versus post hoc tests are discussed. Six types of planned comparison coding are discussed for multivariate analysis of variance (MANOVA).

The Use of A Priori Techniques with a MANOVA

The use of analysis of variance (ANOVA) has existed since 1925 (Fisher, 1925). Since then, ANOVA has become a popular analytic method in social scientific research (Edginton, 1974; Goodwin, & Goodwin, 1985). With the availability of computers, multivariate analysis of variance (MANOVA) has become increasingly more prevalent in research.

The knowledge of a priori analysis has been know at least since 1957, when Suits (1957) first wrote about dummy variable coding. During the 1960s, several researchers (Edwards, 1960; Jennings, 1967; Cohen, 1968; Kirk, 1968; Bottenberg, & Ward, 1963; Overall, & Spiegel, 1969) began to write about coding columns (also called contrast coding) used in multiple regression. This was the initial introduction to the idea that multiple regression was the general linear model.

Performing a "traditional" MANOVA with more than two level in a way will require post hoc tests if a significant F is found (Thompson, 1987). Post hoc tests such as Scheffe, Tuckey, and Boneferroni would be used. This type of procedure is often called unplanned multiple comparison testing and has been considered "data snooping" by performing any or all conceivable comparisons between means and the test of significance was therefore more conservative (Kerlinger, & Pedhauzer, 1975; Kirk, 1968).

Planned comparisons (also called a priori) refines the research focus by isolating the hypotheses to be tested (number

of levels in the way - 1). Thompson (1987) discussed that a priori comparisons increases the power of the analysis, although the experimentwise error rate is increased. Even through unplanned comparisons compensate for the experimentwise error rate (Games, 1971) the overall probability of a Type I error is increased (Horvath, 1985).

Orthogonal vs. Nonorthogonal Comparisons

Planned comparisons can be either orthogonal or nonorthogonal. Typically the sets of "contrasts" are weighted (Thompson, 1985). As Thompson (1987) discussed, for the contrasts to be uncorrelated or orthogonal "each contrast sums to zero and where the cross-products of each pair of contrasts all sum to zero as well" (p. 8). When the contrasts are orthogonal so are the hypotheses.

Nonorthogonal planned comparisons have also been proposed. Winer (1971, p. 175) argued that, "the type of comparisons make little or no difference if comparisons have some meaning in terms of the experimental variable." However, Kachigan (1986) notes that both individual tests and experimentwise significance is known with orthogonal comparisons which are not generally available with nonorthogonal comparisons. Kappel (1982) also suggests that orthogonal comparisons are superior due to the decisions of one null hypothesis is uninfluenced by any of the other null hypotheses.

Several Orthogonal Contrasts

Stepwise multiple regression (for the ANOVA) or canonical correlation (for the MANOVA), a simple correlation of the dependent variable (Y) and a single coding column (X_i) is a point-biserial correlation whose square is the proportion of Y variance (Cohen, 1968). The coding columns also provide the size of the relationship in the sample and can be tested for significance and confidence intervals.

The number of coding columns required is k-1, where g is the number of levels. Thus there is K_i, where i is from 1 to k-1. This is a requirement since the independent variable must satisfy the nonsingularity condition of the matrix. What this means is that for the given matrix (A) that is n x n, there exists a (B) n x n matrix for which they are multiplicative inverses (Yaqub, & Moore, 1980). If the additional coding column K_k was included in the matrix, the nonsingularity condition would be violated because than any of the (K_i) would yield R=1.00 (Cohen, 1968).

There are numerous type of contrast that have been developed throughout the years. In SPSSx there is a subcommand under MANOVA that incorporates six contrasts and the ability of the researcher to input his own special contrasts. These contrasts could be used in multiple regression as well as multivariate analysis of variance. The subcommand in MANOVA is CONTRAST.

The examples that will be used in this paper is taken from a study done with English and reading students at the University of New Orleans. Engl 0150 is a remedial English class; Engl 0230 is

a remedial reading and English class; and Engl 1158 is the final required English composition course for undergraduate students. The class the student was attending was the independent variable (having three levels: 0150, 0230, and 1158). The dependent variables were Nelson Denny raw scores of comprehension and reading rate.

Helmert

Helmert is a specific comparison. It compares levels of a factor with the mean of the subsequent level. The general formula for Helmert is:

$$\begin{array}{ll} \text{mean} & \begin{bmatrix} 1/k & 1/k & \cdots & 1/k & 1/k \\ 1 & -1/(k-1) & \cdots & -1/(k-1) & -1/(k-1) \\ 0 & 1 & \cdots & -1/(k-2) & -1/(k-2) \\ & & \ddots & & \\ 0 & 0 & 1 & -1/2 & -1/2 \\ 0 & 0 & \cdots & 1 & -1 \end{bmatrix} \\ \text{df(1)} & \\ \text{df(2)} & \\ \vdots & \\ \text{df(k-2)} & \\ \text{df(k-1)} & \end{array}$$

The Helmert is orthogonal. To understand this, look at the specific case in. Class has three levels, so the Helmert matrix would look like:

$$\begin{array}{ll} \text{mean} & \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ 1 & -1/2 & -1/2 \\ 0 & 1 & -1 \end{bmatrix} \\ \text{df(1)} & \\ \text{df(2)} & \end{array}$$

The sum of the rows in this matrix (which are the coding columns as we previously learned) sum to zero. Also if you sum across the coding columns or [df(1) and df(2) = 1 + 1/2 - 3/2] and then sum those products, you also get zero. Thus, the Helmert formula is orthogonal.

The hypotheses tested by the three level case above are:

$$ {}_1H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0130} = \frac{\begin{bmatrix} X \\ Y \end{bmatrix}_{0230} + \begin{bmatrix} X \\ Y \end{bmatrix}_{1158}}{2} $$

$$ {}_2H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0230} = \begin{bmatrix} X \\ Y \end{bmatrix}_{1158} $$

Simple

Simple compares each level of a factor to the last level. The general formula for simple is:

$$ \begin{array}{ll} \text{mean} & \begin{bmatrix} 1/k & 1/k & \cdots & 1/k & 1/k \end{bmatrix} \\ \text{df(1)} & \begin{bmatrix} 1 & 0 & \cdots & 0 & -1 \end{bmatrix} \\ \text{df(2)} & \begin{bmatrix} 0 & 1 & \cdots & 0 & -1 \end{bmatrix} \\ \vdots & \vdots \\ \text{df(k-1)} & \begin{bmatrix} 0 & 0 & \cdots & 1 & -1 \end{bmatrix} \end{array} $$

For the specific case of Class, with three levels, the Simple matrix would look like:

mean	1/3	1/3	1/3
df(1)	1	0	-1
df(2)	0	1	-1

The simple contrast coding is also orthogonal. Both of the rows representing coding [df(1) and df(2)] sum to zero. Also if you add down the columns, using only df(1) and df(2), this also sums to 0 = 1 + 1 - 2.

For the given Simple matrix above the two hypotheses tested are:

$$_1H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0130} = \begin{bmatrix} X \\ Y \end{bmatrix}_{1158}$$

$$_2H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0230} = \begin{bmatrix} X \\ Y \end{bmatrix}_{1158}$$

Difference

The Difference coding is the reverse of Helmert. Thus, it compares levels of a factor with the mean of the previous level in the factor, as opposed to the subsequent level. The general matrix for Difference is:

mean	1/k	1/k	1/k	.	.	.	1/k
df(1)	-1	1	0		.		0
df(2)	-1/2	-1/2	1		.		0
.					.		
.					.		
.					.		
.					.		
df(k-1)	-1/(k-1)	-1/(k-1)	-1/(k-1)		.		1

In the case of the three level way, Class, the Difference matrix would look like:

mean	1/3	1/3	1/3
df(1)	-1	1	0
df(2)	-1/2	-1/2	1

Once again, the Difference coding is also orthogonal since the rows sum to zero and the columns, omitting the mean row, summed together also equal zero. The two hypotheses for the above matrix are:

$$ {}_1H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0130} = \begin{bmatrix} X \\ Y \end{bmatrix}_{0230} $$

$$ {}_2H_0: \frac{\begin{bmatrix} X \\ Y \end{bmatrix}_{0130} + \begin{bmatrix} X \\ Y \end{bmatrix}_{0230}}{2} = \begin{bmatrix} X \\ Y \end{bmatrix}_{1158} $$

Repeated

The Repeated coding compares adjacent levels of a factor. As you will see with the specific example, the Repeated coding is also orthogonal. SPSSx Inc (1985) has stated that Repeated coding is useful in profile analysis or where even difference scores are needed. The general form of the Repeated coding matrix is:

mean	1/k	1/k	1/k	. .	1/k	1/k
df(1)	1	-1	0	.	0	0
df(2)	0	1	-1	.	0	0
.				.		
.				.		
.				.		
.				.		
df(k-1)	0	0	0	. .	1	-1

For the specific case, CLASS, the Repeated coding matrix is:

mean	1/3	1/3	1/3
df(1)	1	-1	0
df(2)	0	1	-1

The hypotheses tested in this coding include:

$$ {}_1H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0130} = \begin{bmatrix} X \\ Y \end{bmatrix}_{0230} $$

$$ {}_2H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0230} = \begin{bmatrix} X \\ Y \end{bmatrix}_{1158} $$

Deviation

The Deviation coding takes the deviation from the grand mean. The default is to omit the last category, this is a reference category. The deviation effect for this reference category equals the negative sum of the deviations for the other category, since the deviations must sum to zero.

It is possible to have another category other than the last one be the reference category. To do this you would specify which of the categories you want omitted. The general Deviation matrix is:

mean	1/k	1/k	1/k	1/k
df(1)	1-(1/k)	-1/k .	-1/k	-1/k
df(2)	-1/k	1-(1/k) .	-1/k	-1/k
.		.		
.		.		
.		.		
.		.		
df(k-1)	-1/k	-1/k	1-(1/k)	-1/k

Given the printout with Class, the three level way with the last category as the reference, the Deviation matrix looks like:

mean	1/3	1/3	1/3
df(1)	2/3	-1/3	-1/3
df(2)	-1/3	2/3	-1/3

As like the others before, the Deviation coding is orthogonal. The proof of this is left up to the reader. The hypotheses for this Deviation matrix are:

$$ {}_1H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0130} = \frac{\begin{bmatrix} X \\ Y \end{bmatrix}_{0230} + \begin{bmatrix} X \\ Y \end{bmatrix}_{1158}}{2} $$

$$ {}_2H_0: \begin{bmatrix} X \\ Y \end{bmatrix}_{0230} = \frac{\begin{bmatrix} X \\ Y \end{bmatrix}_{0130} + \begin{bmatrix} X \\ Y \end{bmatrix}_{1158}}{2} $$

If you wanted to use the second category as the reference category for the Deviation coding, the command would be:

CONTRAST (CLASS) = DEVIATION (2)

The matrix would look like:

mean	1/3	1/3	1/3
df(1)	2/3	-1/3	-1/3
df(2)	-1/3	-1/3	2/3

Notice the reference category always has -1/3 in every position.

Other Available Contrasts

There are two additional contrast not presented above. These are Polynomial and Special. Polynomial coding was not appropriate for this data. For Polynomial coding, interval

coding must be used with the way. Such as, there are three groups working on the computer; one group for 10 minutes, the second for 20 minutes, and the third for 30 minutes. The levels must be constant intervals, in this case intervals of 10 minutes.

Special coding can also be used. This is the coding of any other contrasts not mentioned above. The researcher is allowed to set up the matrix for the computer to use to derive the contrasts. Thus, the researcher is not limited to the five previously mentioned contrasts.

Importance of Contrasts

The various methods of contrast coding are important since each method tests a different combination of hypotheses (See Appendix A). Thus, it is important to decide which hypotheses are of the utmost concern and pick the coding that would test those hypotheses.

Appendix B contains sample printouts of not using coding with the three level way and using various coding. A second independent variable is included, sex, to illustrate that no matter what contrast coding is used or no contrast coding, that a two level way is not affected. Note that a given hypotheses has the same lambda regardless of the contrast coding employed. This is due to the fact that the division of the sum of square for a given hypotheses is constant. But, the total amount of the sum of squares may change due to the combination of hypotheses.

Summary

Contrast coding requires the research to plan the research study more carefully but increases the power of the study due to the a priori nature of the study. This is a valuable trade off. The power could make the difference if the researcher is interested in statistical significance. But, contrast coding focuses the study for the researcher and the reader of research.

Regardless of using SPSSx, these contrast codings can be easily used through the use of if...then statements. Using the general matrix, statements could be written to create these contrasts. An example of if...then statements to create the contrast coding "Difference" is in Appendix C. Thus, there is NO excuse for someone not to use contrast coding.

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APPENDIX A

Comparison of Contrast Coding Hypotheses

ENGL 0130 = ENGL 0230 Difference Repeated	$\frac{\text{ENGL 0130 + ENGL 0230}}{2}$ = ENGL 1158 Difference
ENGL 0130 = ENGL 1158 Simple	$\frac{\text{ENGL 0130 + ENGL 1158}}{2}$ = ENGL 0230 Deviation
ENGL 0230 = ENGL 1158 Helmert Simple Repeated	$\frac{\text{ENGL 0230 + ENGL 1158}}{2}$ = ENGL 0130 Helmert Deviation

APPENDIX B

MANOVA Tables for the Various Contrast Codings

Table 1
No Contrast Coding Employed

Hypothesis	Value	Approx. F	Hypoth. DF	Sig. of F
CLASS BY SEX	.97152	1.25874	4.00	.286
SEX	.99330	.58315	2.00	.559
CLASS	.80843	9.70425	4.00	.000

Note. F statistic is WILK'S Lambda.

Table 2
Helmert Contrast Coding Employed

Hypothesis	Value	Approx. F	Hypoth. DF	Sig. of F
CLASS BY SEX	.97152	1.25874	4.00	.286
SEX	.99330	.58315	2.00	.559
CLASS (1)	.98539	1.28277	2.00	.280
CLASS (2)	.82042	18.93418	2.00	.000

Note. F statistic is WILK'S Lambda.

APPENDIX B (cont.)

Table 3
Simple Contrast Coding Employed

Hypothesis	Value	Approx. F	Hypoth. DF	Sig. of F
CLASS BY SEX	.97152	1.25874	4.00	.286
SEX	.99330	.58315	2.00	.559
CLASS (1)	.93633	5.88152	2.00	.003
CLASS (2)	.82042	18.93418	2.00	.000

Note. F statistic is WILK'S Lambda.

Table 4
Repeated ~~Difference~~ Contrast Coding Employed

Hypothesis	Value	Approx. F	Hypoth. DF	Sig. of F
CLASS BY SEX	.97152	1.25874	4.00	.286
SEX	.99330	.58315	2.00	.559
CLASS (1)	.94012	5.50972	2.00	.005
CLASS (2)	.82042	18.93418	2.00	.000

Note. F statistic is WILK'S Lambda.

APPENDIX B (cont.)

Table 5
Deviation Contrast Coding Employed

Hypothesis	Value	Approx. F	Hypoth. DF	Sig. of F
CLASS BY SEX	.97152	1.25874	4.00	.286
SEX	.99330	.58315	2.00	.559
CLASS (1)	.98539	1.28277	2.00	.280
CLASS (2)	.85783	14.33543	2.00	.000

Note. F statistic is WILK'S Lambda.

APPENDIX C

Use of If...Then Statements for Difference Contrast Coding

If and Compute statements can generate coding columns

The first way is called W, with three levels.
The second way is called Z, with two levels.

```
If (W = 1) W1 = -1
If (W = 2) W1 =  1
If (W = 3) W1 =  0
If (W1 <> 0) W2 = -1
If (W = 3) W2 = 2
If (Z = 1) Z1 = -1
If (Z = 2) Z1 =  1
Compute W1Z1 = W1 * Z1
Compute W2Z1 = W2 * Z1
```